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ABSTRACT

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Metamemorial Knowledge, M-space, and Working Memory Performance in Fourth Graders

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Metamemorial Knowledge, M-space, and Working Memory Performance in Fourth Graders

Abstract

Three groups of fourth graders who differed on a metamemory pretest were compared on five working memory tasks to explore the relationship between metamemorial knowledge, total processing space (M-space), and working memory span performance. Children in each group received three versions of each task on concurrent days. It was hypothesized that the group highest in metamemorial knowledge would score highest on the five working memory tasks. Results indicated that the metamemory performance consistently predicted performance on the memory span measures. Three of the memory span measures showed a significant between-group effect on metamemory, while the remaining two evidenced strong trends. Analysis of repeated measures revealed no significant trials effects, indicating that no improvement in performance occurred across repeated presentations of the tasks. Implications for a metacognitive explanation of working memory processes and educational implications are discussed.

The conceptualization of a limited-capacity short term memory system (Miller, 1956) has recently been extended to include both processing and storage functions (Baddeley & Hitch, 1974). This dynamic conceptualization of working memory includes processing and storage components which compete for the available working memory space. Case, Kurland & Goldberg (1982) investigated the trade-off between the processing and storage functions of working memory and concluded that processing efficiency is the main determinant of working memory span performance. Specifically, they found that when speed of encoding was controlled, adults and children were equivalent in working memory span performance. Within their conceptualization, efficient processing functions require less working memory capacity, and thus permit more of the limited working memory space to be allocated for the storage of the material to be remembered.

This shift in emphasis from a static short-term memory system to a dynamic processing approach has resulted in the development of working memory tasks which are designed to place heavy demands on both processing and storage functions. One of these newly-developed tasks is the Listening Span task (Daneman & Carpenter, 1980). This task requires the child to make true/false judgments for a series of sentences, while simultaneously preparing to recall the last word of each sentence when signalled to do so. The heavy task demands, it was argued, make it a better measure of working memory capacity than traditional measures like backward digit span.

Working memory span performance has also been explained as resulting from the use of chunking and other mnemonic strategies (Dempster, 1978; Trabasso & Foellinger, 1978). According to this view, individual differences in span performance reflect the use of various mnemonic strategies, either in encoding the materials or in their subsequent organization. Within this conceptualization, metamemorial knowledge should be substantially related to

span performance, since it is seen as guiding the development, monitoring, and modification of mnemonic strategies (Brown, 1978; Flavell & Wellman, 1977).

Another conceptualization of working memory span performance centers on the concept of "M-space" (Pascual-Leone, 1970). According to this view, total working memory space grows linearly during the early school years, and the total processing space in working memory (M-space) is the main determinant of span performance. M-space is defined as the number of mental schemes that an individual can simultaneously employ during a problem solving task. Larger m-space capacity is equated with more working memory space in which both processing and storage functions can operate. Tests of M-space are derived from performance on the Raven's Standard Progressive Matrices.

In summary, if mnemonic strategies and chunking are major determinants of memory span performance (Dempster, 1978; Trabasso & Foellinger, 1978), there should be significant metamemory group differences in working memory span performance and metamemory scores should correlate significantly with all working memory span measures. If total processing space is the central determinant of working memory span performance (Pascual-Leone, 1970), the M-space measure should be significantly related to span performance and there is no reason to expect significant metamemory group differences in span performance. If processing efficiency is the primary determinant of span performance (Case et al., 1982), neither M-space nor metamemory should be major determinants of span performance. Practice should be the major determinant and the repeated trials might show significant changes in recall performance.

This study was conducted to explore the relationship between performance on working memory tasks, metamemorial knowledge, and M-space in fourth grade children. In accord with the strategy-use explanation of memory span performance (Dempster, 1978; Trabasso & Foellinger, 1978), it was hypothesized

that those subjects who score highest on the metamemory battery would perform best on the memory span tasks. Five memory span tasks were used, and each was given three times. The memory span tasks chosen include: Forward and Backward Digit Spans, Forward and Backward Word Spans, and Listening Span. The variety of tasks allows an examination of the role of metamemorial knowledge and performance on working memory span tasks of varying novelty and complexity.

Method

Subjects

Fifty-one fourth grade students enrolled in a public elementary school served as subjects. The subjects were predominantly of middle- to upper-middle socioeconomic backgrounds and all were native speakers of English.

Procedure

In a single group test session seventy-five children received a metamemory battery (Belmont & Borkowski, in press) and the Standard Progressive Matrices test (Raven, 1958). The scaling methods of Bereiter & Scardamalia (1979), were used to obtain the M-Space estimates from the Ravens' scores. The metamemory battery contained: three questions in which the child was asked to judge whether they could recall more words from a longer categorized word list or from a shorter non-categorized word list; a question in which they were asked to generate mnemonic strategies for remembering to take a pair of skates to school the next day; and four questions in which they were asked to chose the most efficient allocation of study time for recall of word lists of various lengths after preliminary instruction on two different "cumulative rehearsal - fast finish" recall strategies. In addition, they were asked at the beginning and again at the end of the session to predict their free recall performance on a fifteen-item word list, and their accuracy of prediction was calculated. A single Metamemory score was computed for each child by adding

the Z-scores for the above measures. High, medium, and low metamemory groups were formed, equated on age and M-Space estimates. Each group contained seventeen children, and their mean score on these tasks are presented in Table 1.

Five measures of working memory performance were included, and each task was presented three times to each child. The digit spans, word spans, and listening span tasks were each given on three consecutive days in a small room near the child's classroom. Thus, three testing sessions were administered on each of three tasks, so that each child was seen for nine individual sessions.

The Forward Digit Span and the Backward Digit Span were always given together on the same day as were the Forward and Backward Word Spans. The forward span was always given before the backward span for each measure. Set size ranged from two to eight numbers for Forward Digit Span and from two to seven numbers for Backward Digit Span. There were five sets of numbers at each span level. The word span task was taken from Daneman & Carpenter (1980), with the modification that each span level was lengthed from three sets of words to five sets of words. Set size ranged from two words to six words per set on both Forward and Backward Word Spans. All words were one-syllable common nouns which were phonetically and semantically unrelated.

The Listening Span task was administered separately because of its length. The task was modified for fourth grade students by shortening each sentence to between five and ten words. Spans for all tasks were computed by assigning a span score equivalent to the longest span length at which the child was correct on three of the five sets. An additional .2 points were assigned for each set correct at the next longest span level. Testing was stopped when a child missed three of the five sets at a given span length.

The order in which the child received the Digit Span, Word Span and Listening Span tasks was determined randomly from the six possible

permutations. Three versions of each task were prepared for presentation on consecutive days. The version of each task a child received was systematically varied as well to control for effects due to small differences between different versions of the same task. The three version orders used were; 1 2 3, 2 3 1, 3 1 2. This allowed each version to appear first, last and in the middle for one third of the children.

The Digit and Word Span tasks were recorded on cassette tapes at the rate of one word or digit per second to insure the uniformity of presentation. The tasks were played back on either a Panasonic C100 or a JCV PC-70 cassette deck. Each deck had a five-band graphic equalizer that was used to insure that the playback quality was equivalent. The sentences in the Listening span task were recorded at normal speed and reading intonation. Practice trials were given on the first day a new task was begun. Each child was given unlimited time to try and respond correctly to a set.

Results

No significant effects for task presentation order or task version were found, therefore these factors were dropped from the following analyses.

Span Tasks

Separate 3 (groups) by 3 (trials) repeated measures analysis of variance were computed for Forward and Backward Digit Span. For Forward Digit Span, a significant main effect for groups was found, F $(2,48) = 10.58$, p $<.001$. A Duncan's multiple range test showed that the high metamemory group performed significantly better than both the medium and low metamemory groups which did not significantly differ from each another. No significant effect was found for the repeated trials effect nor was a significant interaction found. See Table 2. While a trend was found toward better performance by the high metamemory group on repeated presentations of the task, the trend was absent for the low and medium metamemory groups. Average span performance across

tasks for all span tasks are presented in Table 3.

No significant main effects were found for Backward Digit Span. The performance of the high metamemory group was higher overall than the other two groups and their performance improved in the same trend as their Forward Digit Span performance.

Separate 3 (groups) by 3 (trials) repeated measures analysis of variance were conducted on both Forward and Backward Word Spans. A significant effect for groups was found for Forward Word Span, F (2, 48) = 7.37, p <.01. A Duncan's multiple range test showed that the high metamemory group performed significantly better than the low and medium groups, which did not differ significantly from each other. No significant effect was found for the repeated trials, and no significant interaction was found. All three groups' performance increased somewhat with repeated trials on this task.

A significant groups effect was found for Backward Word Span, F (2,48) = 6.77, p <.01. A Duncan's multiple range test revealed that the high metamemory group's performance was significantly higher than the low and medium group which did not differ significantly. There was no significant repeated trials effect and no significant interaction was found.

A 3 (groups) by 3 (trials) repeated measures analysis of variance performed on Listening Span revealed no significant main effects or interaction. All three metamemory groups improved slightly across trials.

Individual Differences

Since no significant repeated measure effect was found, the three versions of each task were combined to form an average score for each task. Pearson correlations for all subjects were performed between the average span scores for each of the five tasks and Ravens score, M-space, and the Metamemory score. See Table 4. Significant correlations were found between the Metamemory score and performance on each of the five working memory span

tasks. M-space was significantly correlated with Metamemory, Backward Word Span and Listening Span. The pattern of correlations indicate that a moderate relationship exists between memory task performance and metamemorial knowledge and also between working memory task performance and M-space.

Discussion

These results provide support for a link between metacognitive knowledge (Brown, 1978; Flavell & Wellman, 1977) and strategic performance on working memory tasks. The metamemory group differences in working memory span indicate that children's knowledge about the variables which interact to affect memory performance is an important source of individual differences in working memory task performance.

The hypothesis that the high metamemory group would outperform the other groups on these span tasks was confirmed for three of the five working memory tasks. These results support the position of Dempster (1978), who argued that working memory span performance is a function of mnemonic strategies and chunking. Within this conceptualization, metamemory would seem to be instrumental in the development and use of these mnemonic techniques. This is especially the case for the Forward Digit Span and Forward Word Span tasks. These results can be explained either as metamemorial knowledge guiding the utilization of strategies during testing, or by metamemorial knowledge promoting efficient processing of memory task materials. In the case of strategy use, the lack of a repeated-trials effect suggests that the strategies were not developed over the course of three testing sessions, but rather were part of the child's mnemonic repertoire at task outset.

There were no significant metamemory group differences for Backward Digit Span or Listening Span despite trends in the appropriate direction.

Metamemory scores significantly correlated with all span measures while M-space was found to significantly correlate with the Backward Word Span and Listening Span measures only. It appears that, for simpler span tasks, M-space differences were not related to performance differences. The evidence suggests that performance on traditional short-term memory tasks (those not requiring operations on or transformation of the stored items prior to recall) are influenced more by the child's knowledge of variables which affect memory performance than by their total working memory capacity. This result argues against an interpretation of span differences as due to differences in total processing space available to the child (Pascual-Leone, 1970). However, on tasks specifically designed to tax both the processing and storage functions of working memory, metamemorial knowledge and total processing space may be equally important to performance.

The results indicate that there may not be a strict division between the M-space, processing efficiency, and strategy-use explanations of working memory span performance. Working memory span performance (whether viewed as the result of more efficient processing of materials due to practice or as the result of strategic processes) seems to depend both on the demands of the task used to measure it, and on the child's knowledge of these task demands and his/her own memory system. Specifically, all three explanations of working memory task performance may be explained within a metacognitive framework. Metamemory (Brown, 1978; Flavell & Wellman, 1977) is conceived of as a knowledge base which guides the planning, execution and monitoring of strategic memory operations. A division has recently been drawn (Cavanaugh & Perlmutter, 1982) between the knowledge base concerning memory and the control processes, since simply having memory-relevant knowledge need not lead to the spontaneous execution of strategies. This knowledge base is seen as more accessible to conscious reflection; it requires more conscious and

concentrated effort than the control processes; and it is more likely to transfer across tasks. The control processes, on the other hand, are relatively task-specific and more or less automatized in function, depending on the individual's previous exposure to the material.

This information processing description of executive functions shares many features with the triarchic theory of intelligence (Sternberg, 1984). In this theory, metacomponents guide performance components and knowledge gathering components during task execution. The metacomponents guide the operation of lower components, and are more readily generalized than the lower, more automatized, components.

The three explanations of working memory task performance may simply reflect the operation of executive and performance components in response to differing task demands. Specifically, Case et al. (1982) argue for a processing/storage trade-off in working memory. They argue that as processing becomes more efficient, more of the attentional reserve is available for storage functions. In this conceptualization, metamemory could conceivably play a role in guiding processing functions to become more efficient over repeated presentations of memory tasks, thus freeing up working memory space for storage functions. The tasks used by Case et al. (1982) were designed to place heavy demands on the processing components and to minimize the possibility of strategy use. On these tasks, efficient processing may depend to some extent on metacognitive components for the selection of the most appropriate strategies, but simple automaticity of processing would be more highly related to performance, given the task demands. In this regard, metamemory may play a limited role in guiding the choice of information processing and encoding strategies. Practice-induced automaticity is clearly important to performance on tasks using materials which do not lend themselves to chunking or to the use other mnemonic strategies. However, when materials

can be effectively chunked (Dempster, 1978) or are overlearned, metacognition can be most important in guiding the choice of the the appropriate strategy and its execution. Under these conditions, memory strategy use does indeed occur. The M-space interpretation of memory span can also be conceived of as dependent on the choice of task. Coming, as it does, from the Ravens' Progressive Matrices Test, performance on this task may depend on both an individual's metacognitive knowledge concerning strategies which may be successfully applied to novel problem sets, and an individual's cognitive capacity for simultaneously maintaining several items in working memory. The power of M-space capacity measures for predicting working memory task performance may be dependent on task-relevant differences in the adequacy of an individual's metacognitive component.

The differing conceptions of working memory functioning can be reconciled under an information processing approach which assumes that metacognitive knowledge and attention-free automatized processes develop interactively over repeated task presentations. As automaticity increases, lower-order processes take less monitoring and therefore more cognitive capacity remains for use by the metacognitive components. Conversely, as metacognition develops it becomes more proficient at selecting the appropriate lower-order automatized processes to implement for dealing with a given task. Metacognition will be most highly correlated with performance on moderately novel tasks for which an individual may have readily-available strategies. However, on both highly automatized and highly novel task situations, simple fluency in dealing with the subcomponents of the task may be more predictive of performance. Differences in span performance lend themselves to processing/storage tradeoff explanations when the task minimizes the appropriateness or availability of strategy use, and lend themselves to strategy use explanations when the material allows the use of readily-available strategies.

Developmentally, it seems possible to find a large number of tasks for children at any given age which would either be highly automatized, highly novel, or for which there are readily-available strategies. The choice of educational materials in reading, problem solving, or memory domains can easily affect the approach the child takes toward a task. If the intent of an exercise is to promote metacognitive development, tasks which are relatively novel, but which contain material readily processed with the child's available strategies will be most effective. The task will enrich those metacognitive components involved in the choice, monitoring, and evaluation of strategic processes. If the intent of an exercise is to build automaticity of processing, the material should be invariant, and each item should have the same processing requirements. In light of the interaction between metacognitive and automatized components, a sequence of exercises which progressively build on previously automatized processes, while containing novel elements which require metacognitive processing, seems optimal for the establishment of an active strategic approach to learning. In addition, the number and general type of processing strategies possessed and/or commonly employed by a given child must be taken into account in the design of learning materials.

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Table 1

Group averages on metamemory, m-space ravens, and age

	Metamemory battery	M-space estimates	Ravens score	Age
High	19.59	3.06	40.1	9.77
Medium	13.88	2.94	39.5	9.81
Low	9.00	2.91	38.2	9.85
Maximum score	25.00	4.00	60.00	--

Table 2

F values of a 3(group) by 3(trials) repeated measures analysis of variance for the major measures

Measure	Metamemory Group df(2,48)	Repeated trials df(2,96)	Group by Trials df(4,96)
Forward Digit Span	10.58***	1.56	0.17
Backward Digit Span	2.20	0.72	2.08
Forward Word Span	7.37**	2.29	0.04
Backward Word Span	6.77**	2.40	0.35
Listening Span	2.14	2.36	.59

* = $p < .05$

** = $p < .01$

*** = $p < .001$

Table 3

Average group performance across trials on working memory span tasks

Task	Forward Digit Span			Backward Digit Span			Forward Word Span			Backward Word Span			Listening Span		
Trials	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Metamemory Group															
Low	4.99	4.93	5.13	3.32	3.28	3.21	4.03	4.08	4.14	2.95	3.05	3.02	1.95	1.99	2.03
Medium	5.12	4.92	5.19	3.64	3.36	3.79	3.94	3.99	4.08	2.95	3.15	2.93	1.95	2.12	2.12
High	5.94	5.94	6.05	3.58	3.75	3.73	4.46	4.49	4.61	3.37	3.52	3.42	2.11	2.34	2.54

Table 4

Pearson correlation coefficients between ravens,

m-space, metamemory, and average memory span measures (N=51)

	M-space	Ravens	Forward Digit Span	Backward Digit Span	Forward Word Span	Backward Word Span	Listening Span
Metamemory	.31*	.26*	.46***	.29*	.40**	.42***	.36**
M-space		.83***	.12	.18	.18	.39**	.41***
Ravens			.18	.33**	.22	.38**	.50***
Forward Digit Span				.34**	.79***	.33**	.35**
Backward Digit Span					.16	.52***	.22
Forward Word Span						.31*	.30*
Backward Word Span							.39**

*p <.05

**p <.01

***p <.001